Photosynthesis: Light Reactions

Chapter 8.1-8.2

Biol 1A

California State University, Fresno

Learning Goals

1. Understand how pigments in the chloroplast absorb light energy.
2. Describe a photosystem.
3. Describe the transfer of energy through the light reactions.
4. Explain how ATP and NADPH is produced through the light reactions.

Introduction

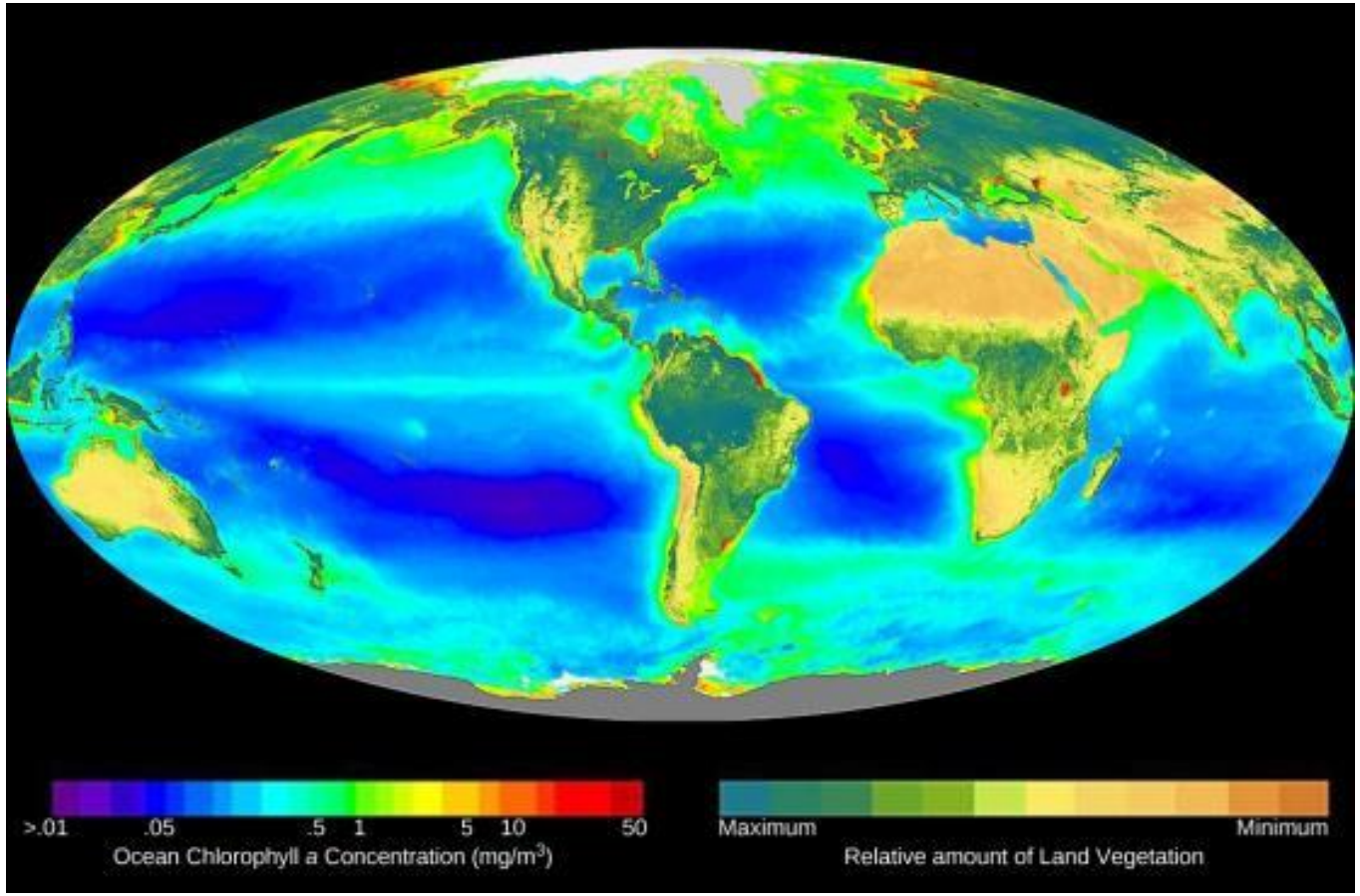
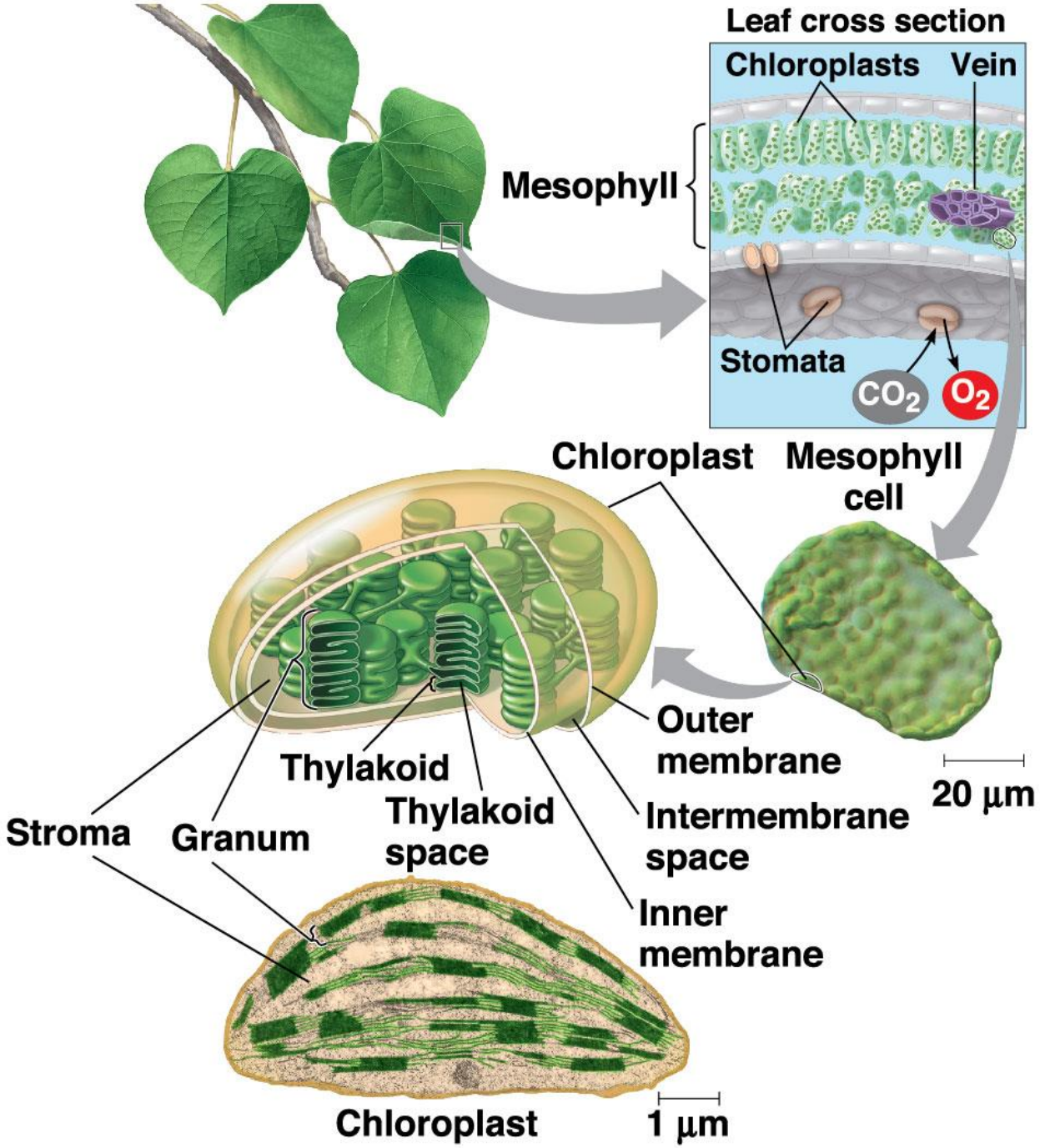


FIGURE 8.1 This world map shows Earth's distribution of photosynthesis as seen via chlorophyll *a* concentrations. On land, this is evident via terrestrial plants, and in oceanic zones, via phytoplankton. (credit: modification of work by SeaWiFS Project, NASA/Goddard Space Flight Center and ORBIMAGE)

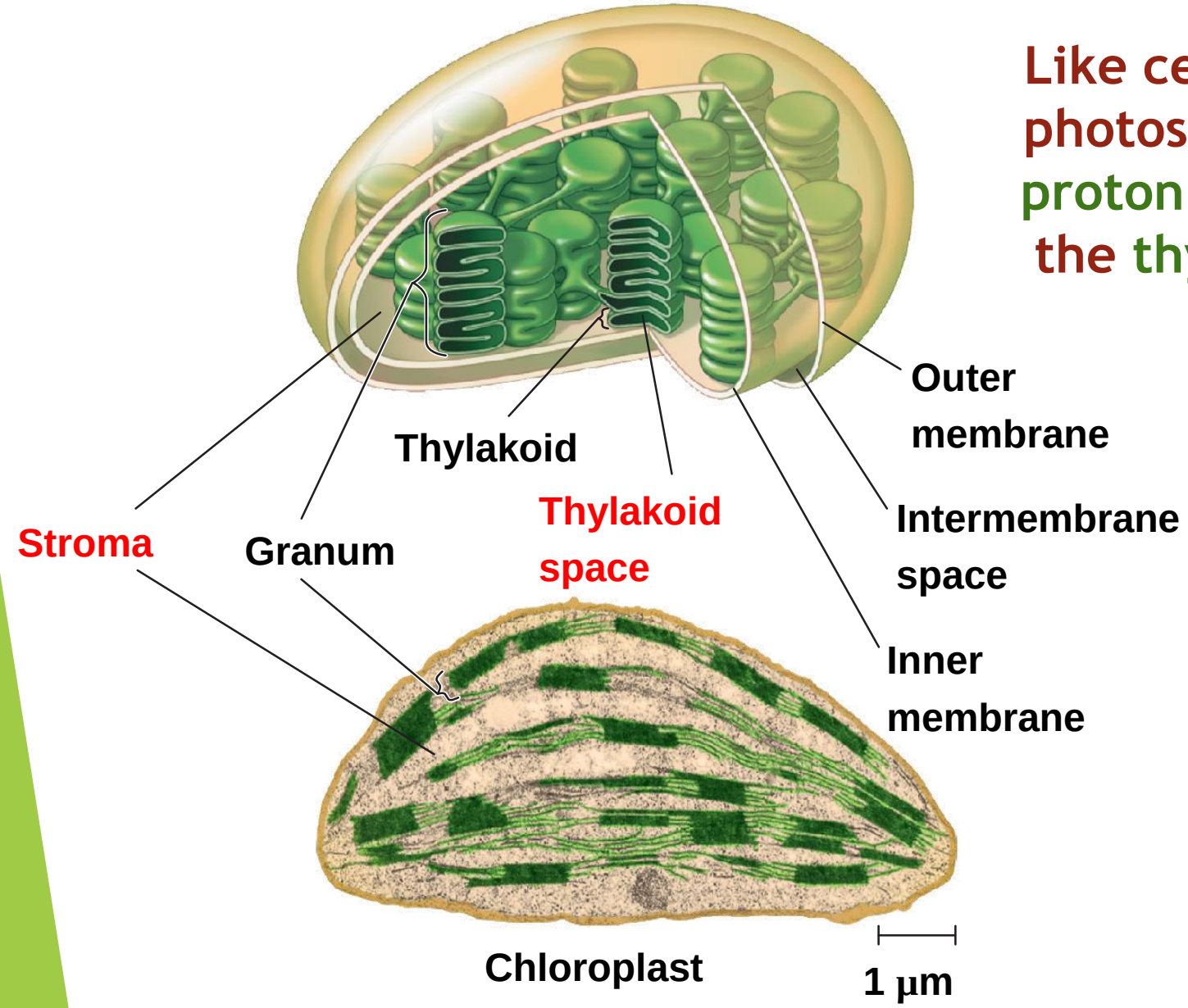
Plants are not the only organisms that can photosynthesize

- **Photoautotrophs** use light to make food (Plants, algae, and a group of bacteria called cyanobacteria)
- **Heterotrophs:** must obtain organic materials form photoautotrphs (animals, fungi, and most other bacteria
- **Chemoautotrophs** synthesize sugars, not by using sunlight's energy, but by extracting energy from inorganic chemical compounds;

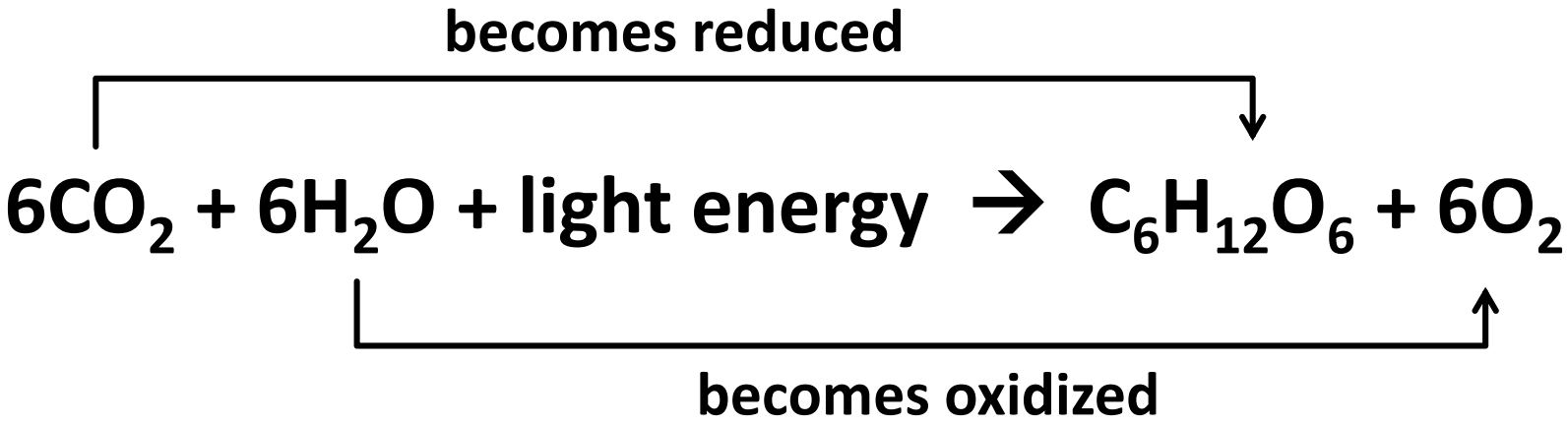


Photosynthesis occurs in chloroplasts

Like cellular respiration, photosynthesis creates a proton gradient between the thylakoid space and stroma



Photosynthesis as a redox reaction



Has a $\Delta G = +686$ kcal/mol
Endergonic
Not spontaneous
Requires energy
Products have higher free energy than reactants

What is going on here?

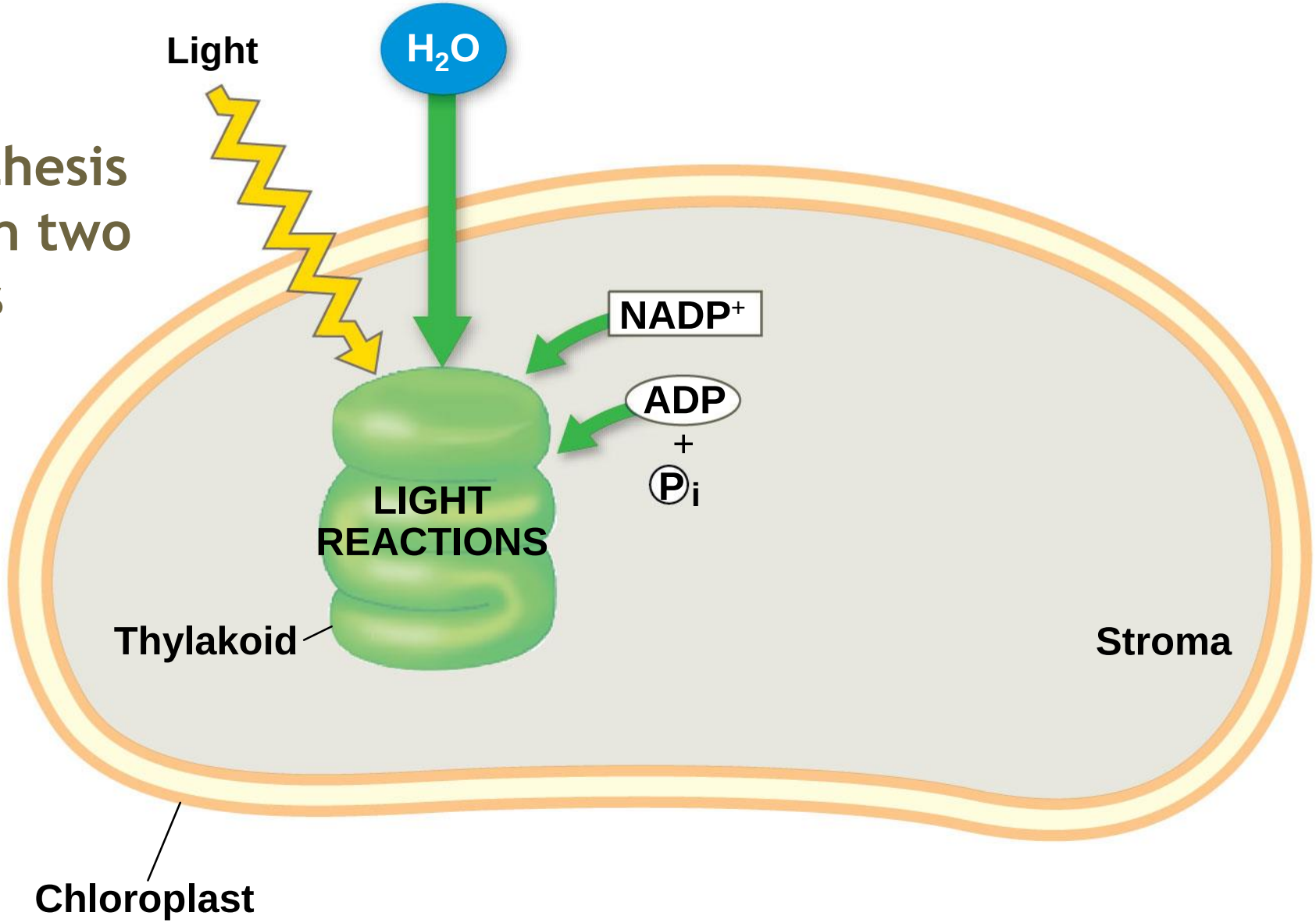
$$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

Hypothesis 1: Carbon atoms from the carbon dioxide combine with the water to make glucose and the remaining oxygen from the carbon dioxide is released as a byproduct

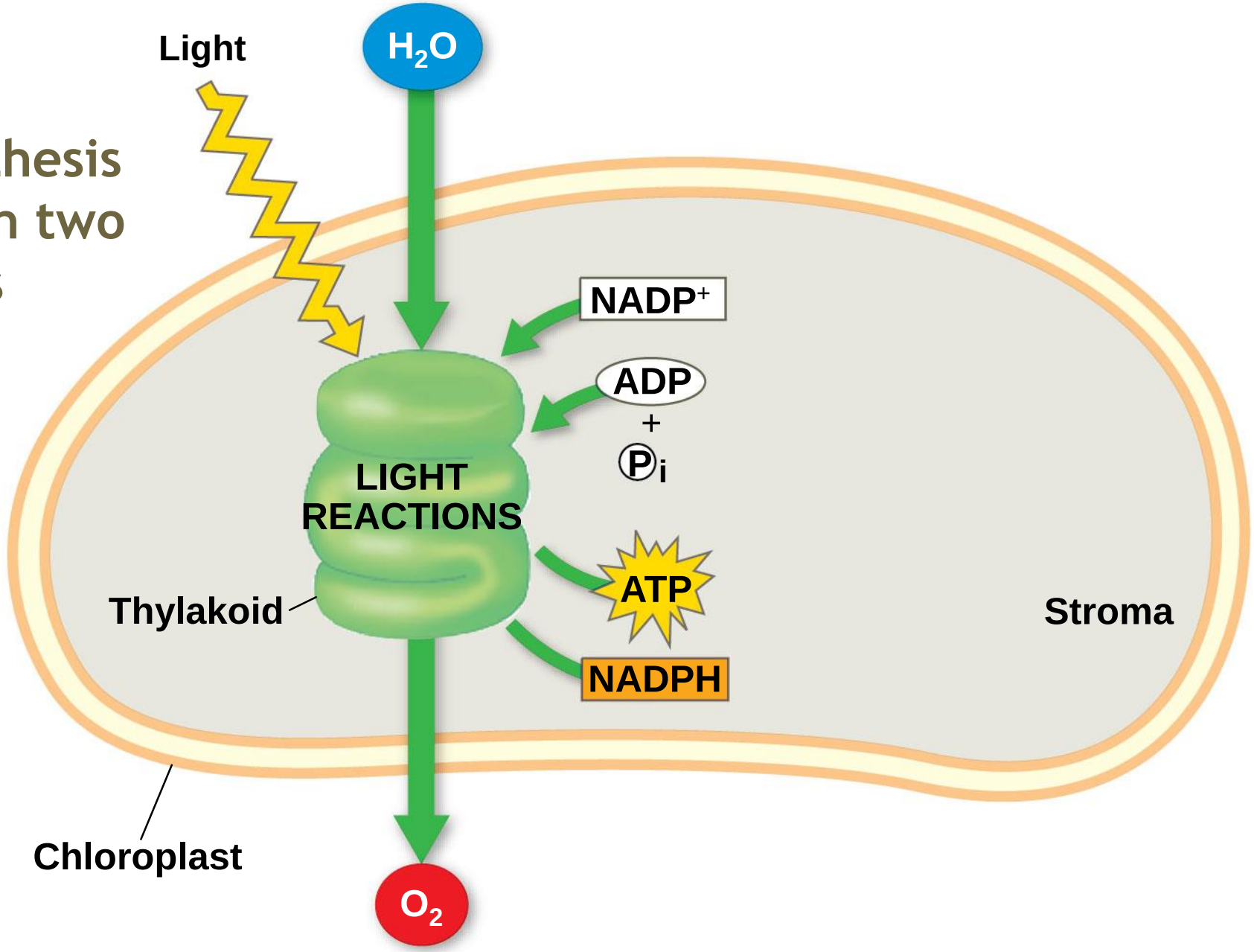
Hypothesis 2: Water is split. The hydrogens from the water combine with the carbon dioxide to make glucose and the oxygen from the water is released as a byproduct.

Photosynthesis splits water!!!

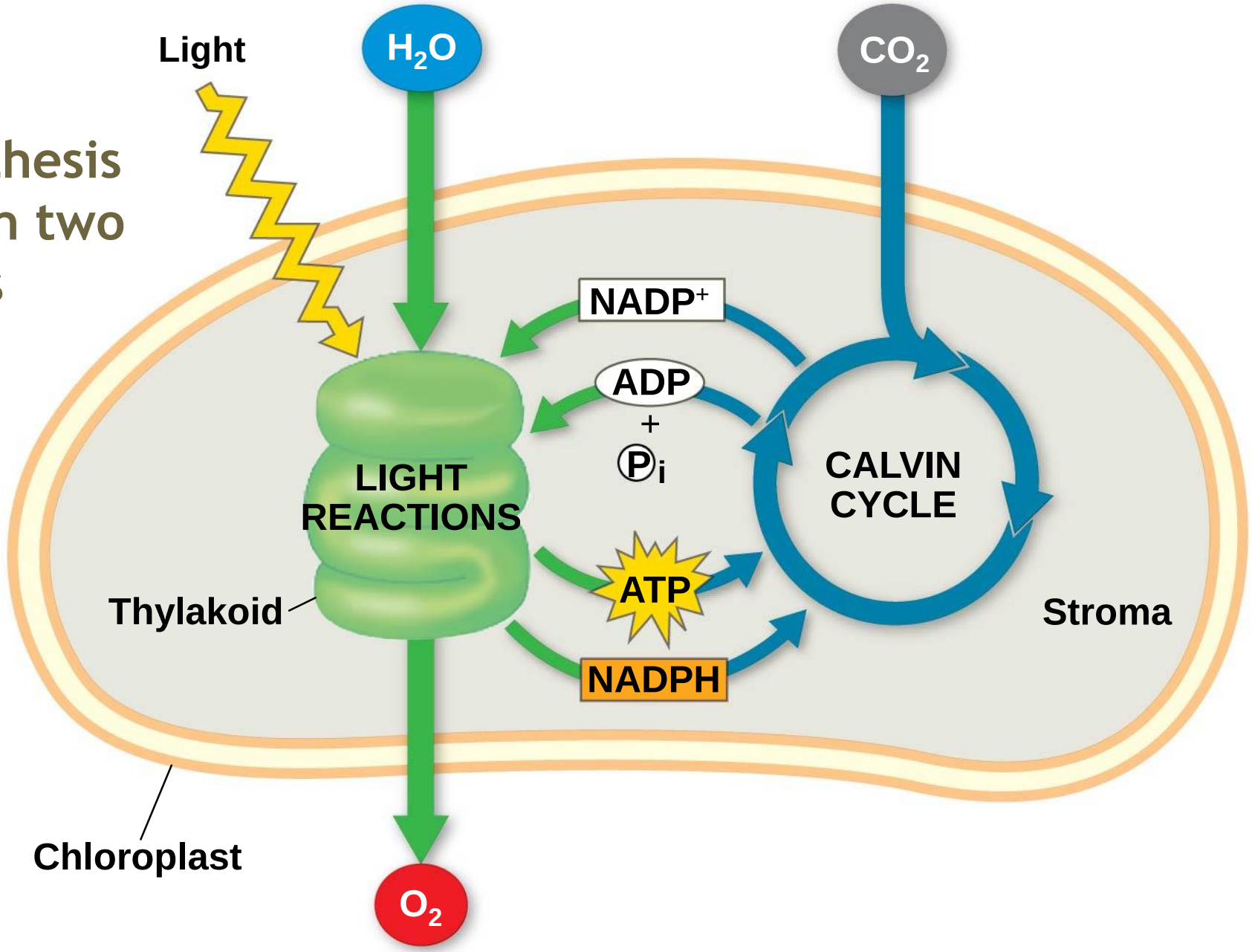
Photosynthesis happens in two steps



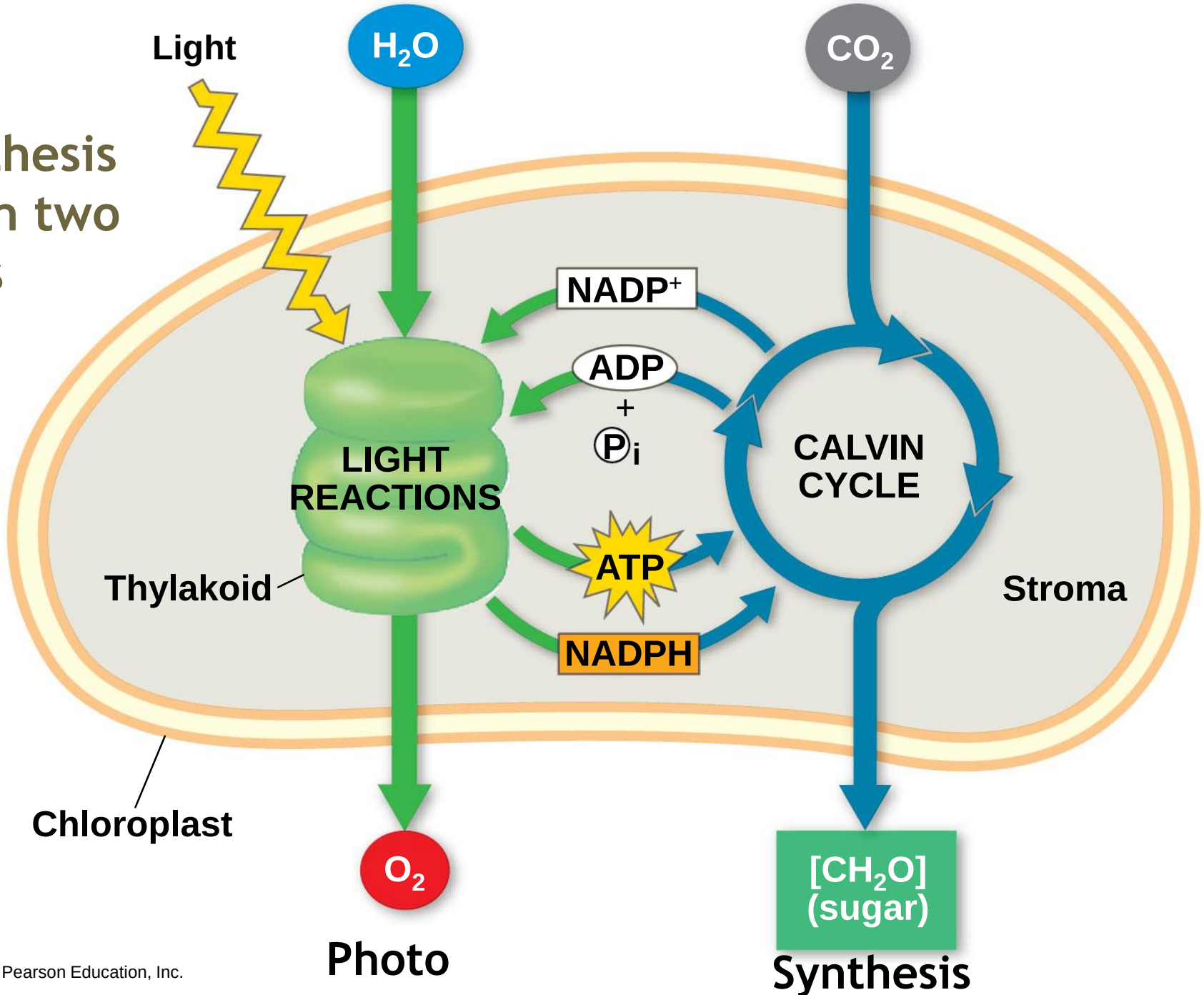
Photosynthesis happens in two steps



Photosynthesis happens in two steps

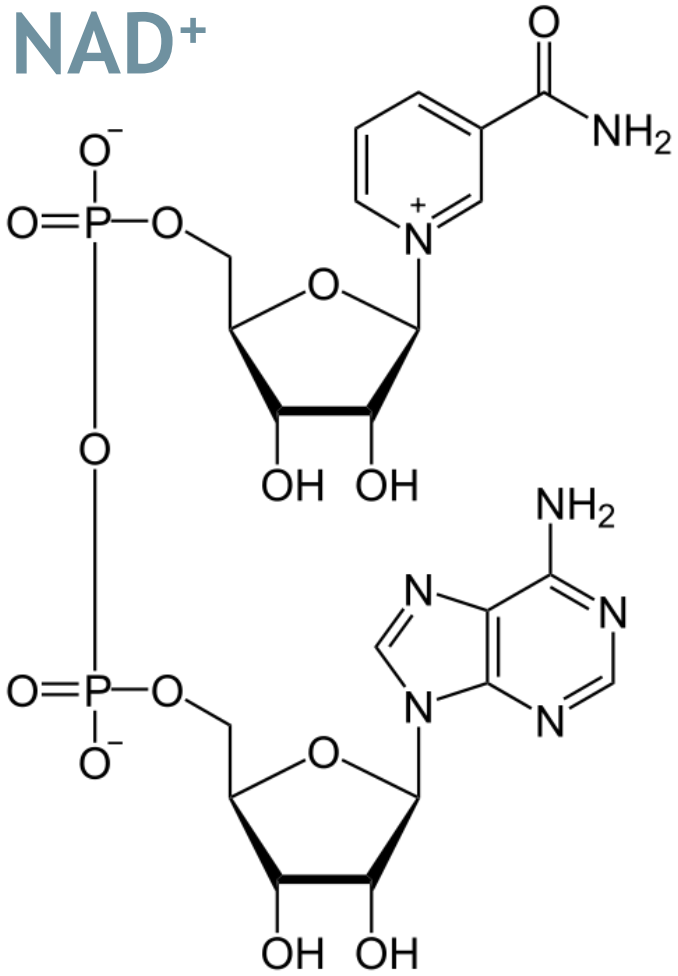


Photosynthesis happens in two steps

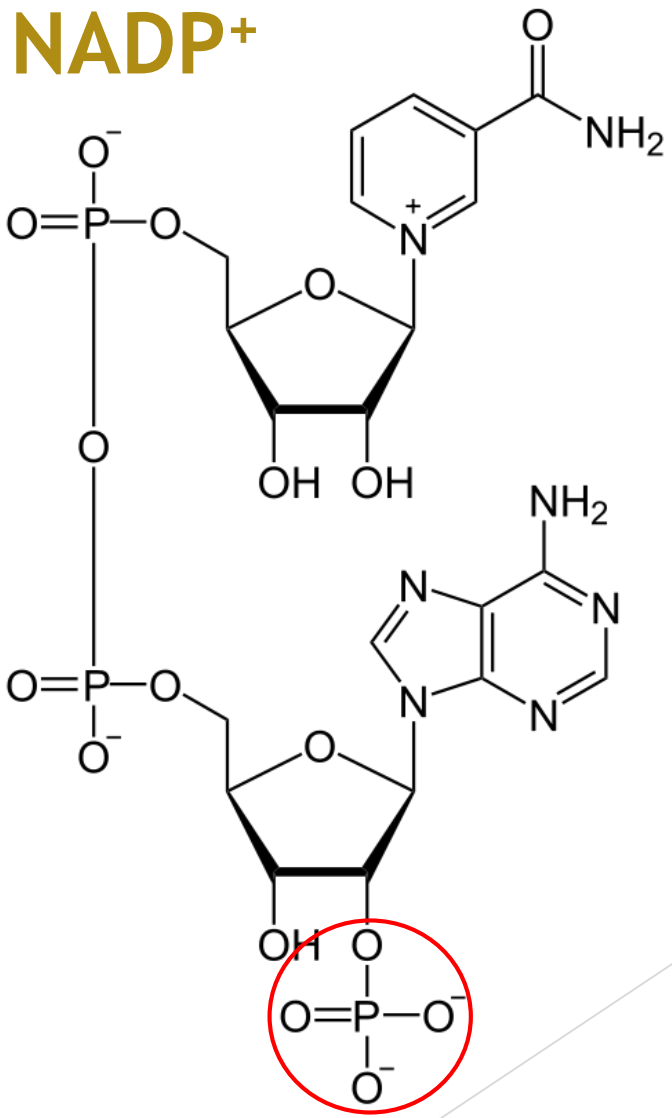


Electron carrier in Photosynthesis is $NADP^+$

NAD^+



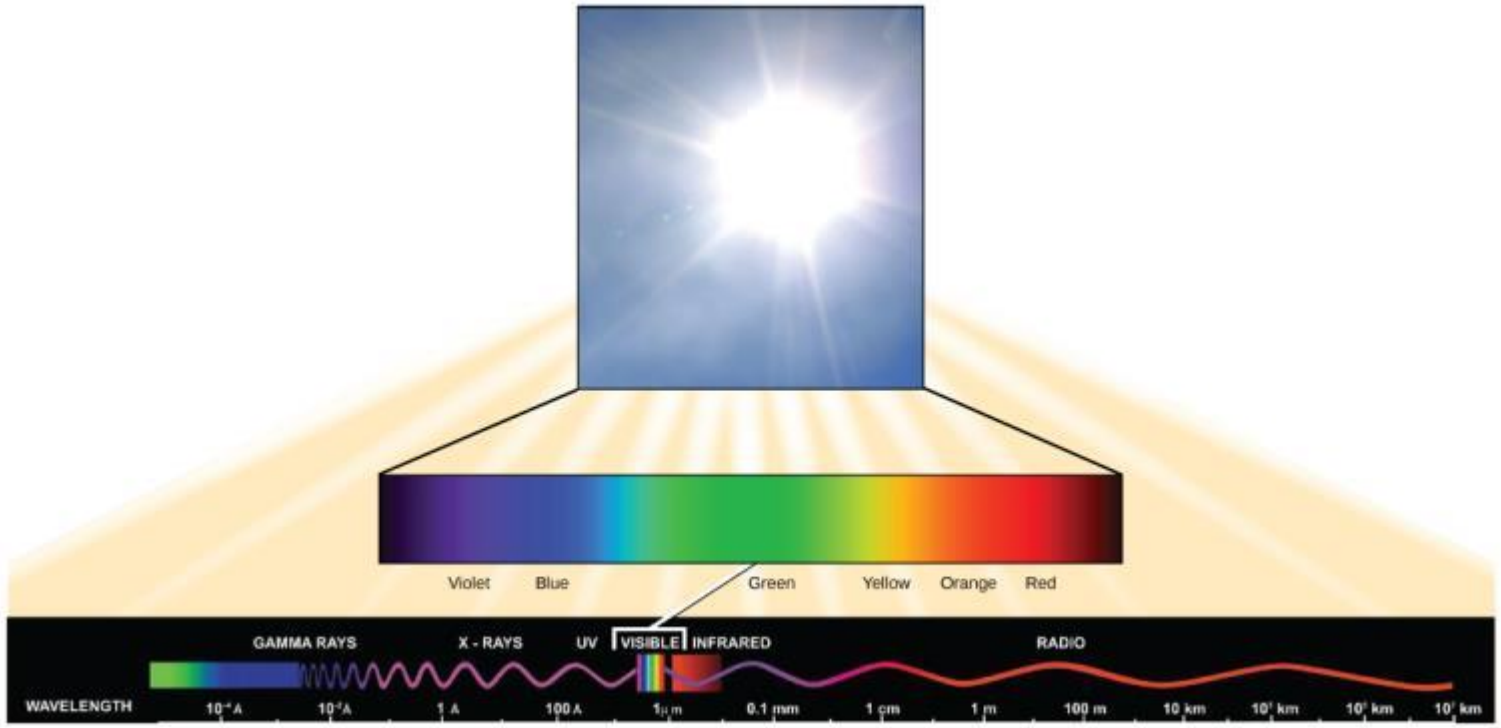
$NADP^+$



Electromagnetic Spectrum

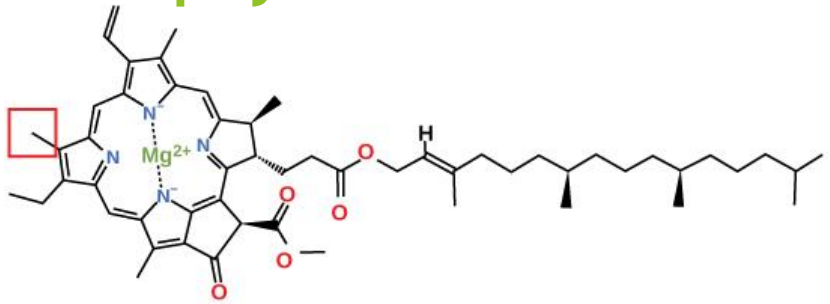
- The electromagnetic spectrum is the range of all possible frequencies of radiation. The difference between wavelengths relates to the amount of energy carried by them.

- Photosynthesis absorbs wavelengths of visible light.



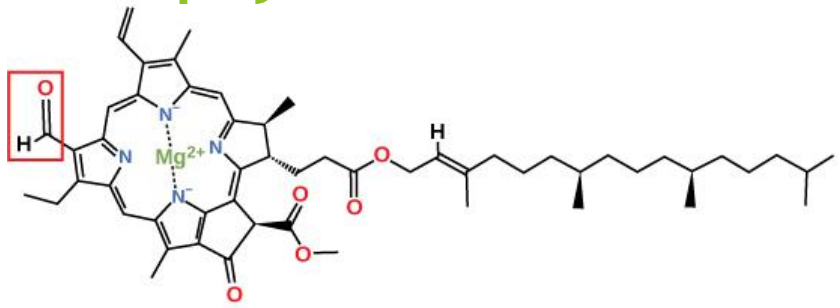
Pigments in Photosynthesis

Chlorophyll a



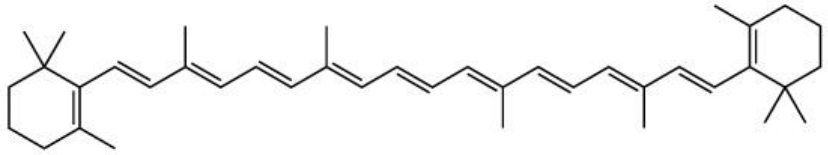
(a)

Chlorophyll b

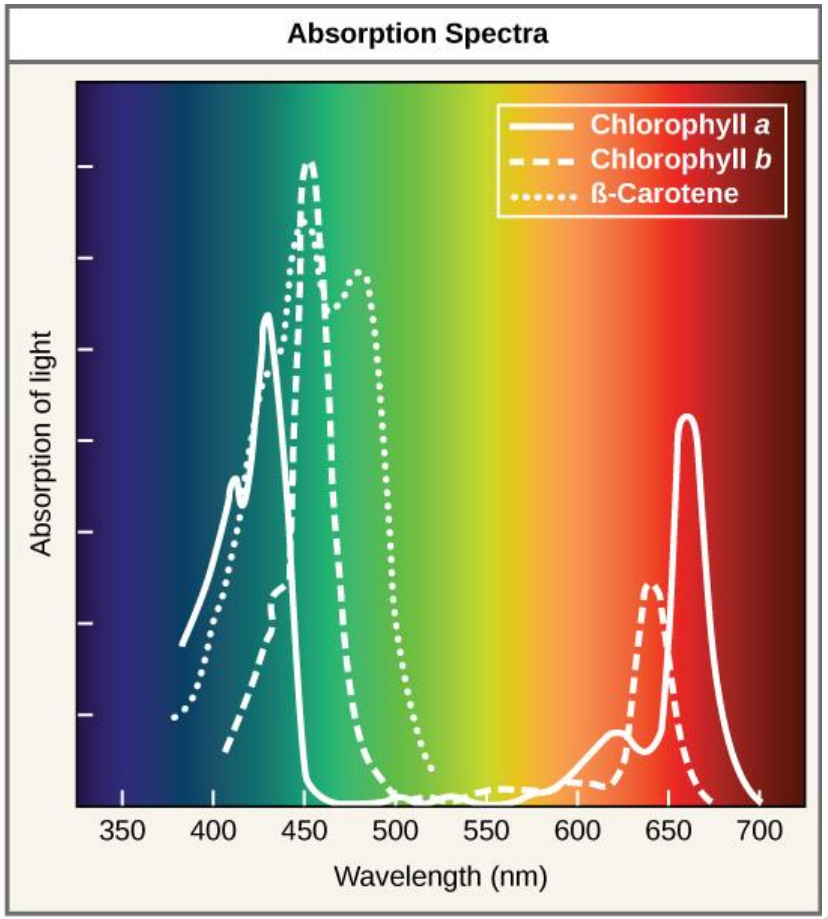


(b)

Beta-Carotene

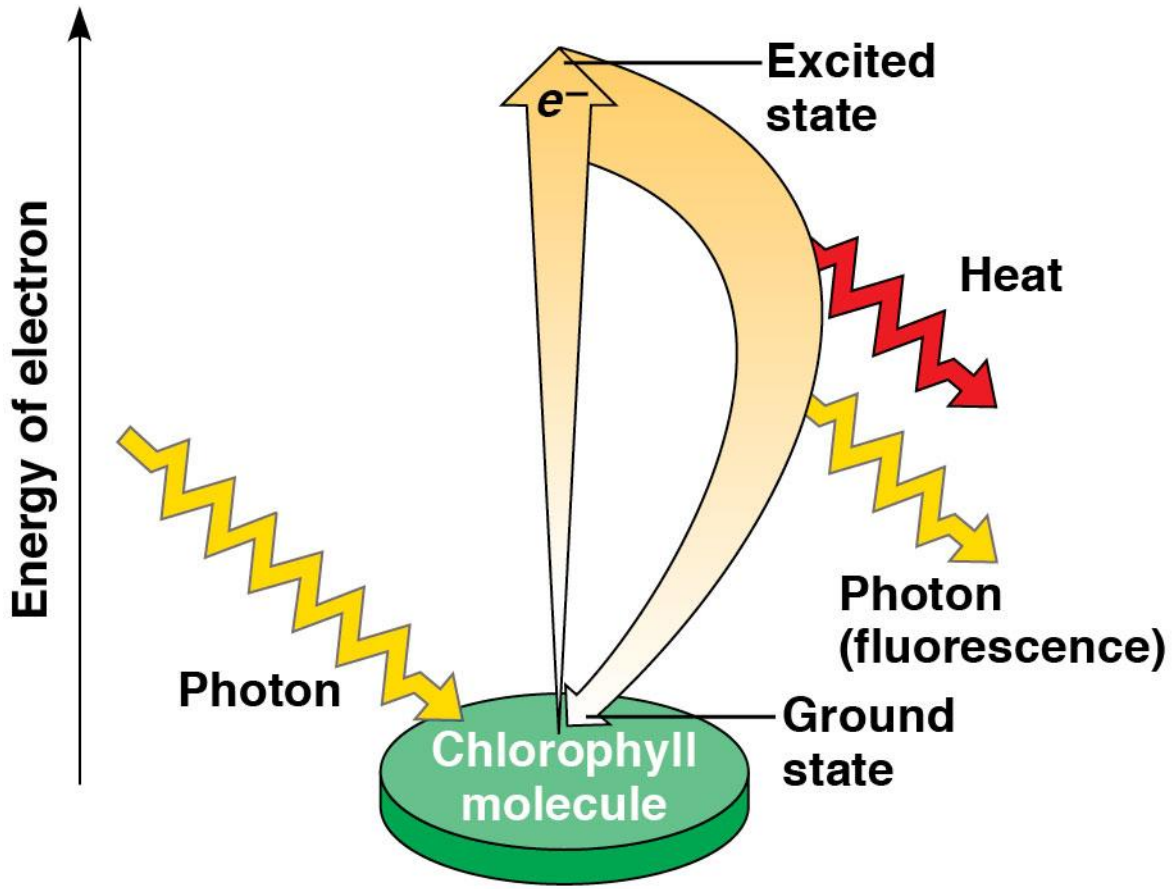


(c)



(d)

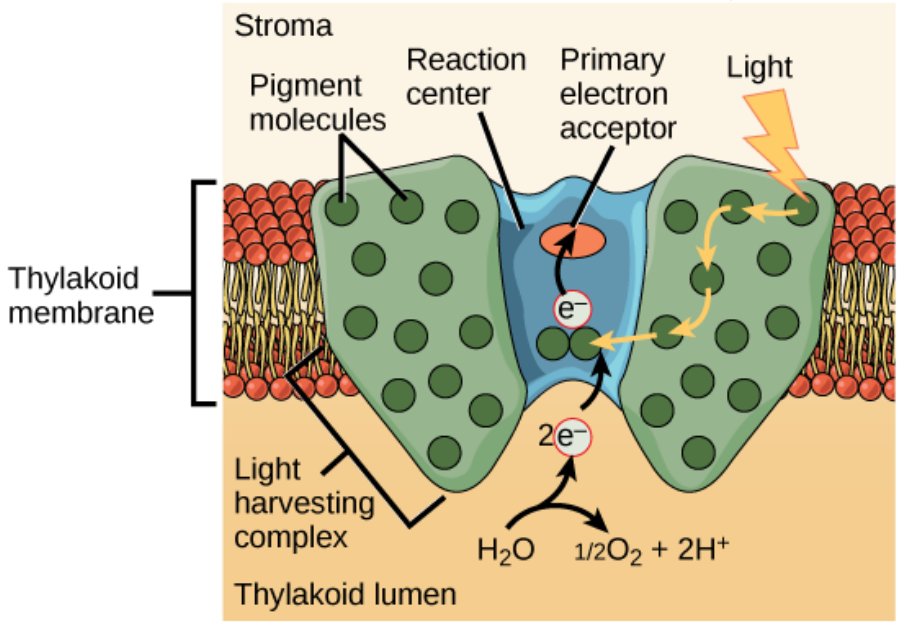
Pigments absorb specific wavelengths of visible light



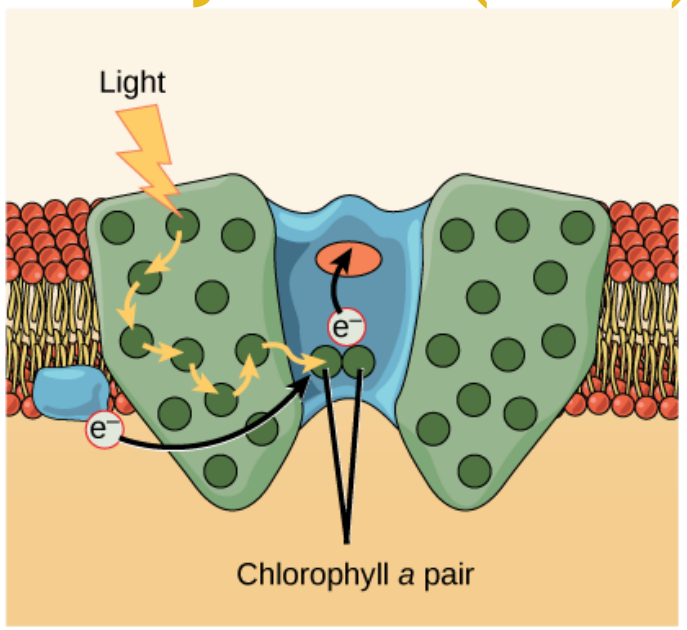
(a) Excitation of isolated chlorophyll molecule

Photosynthesis requires two Photosystems located in the thylakoid membrane

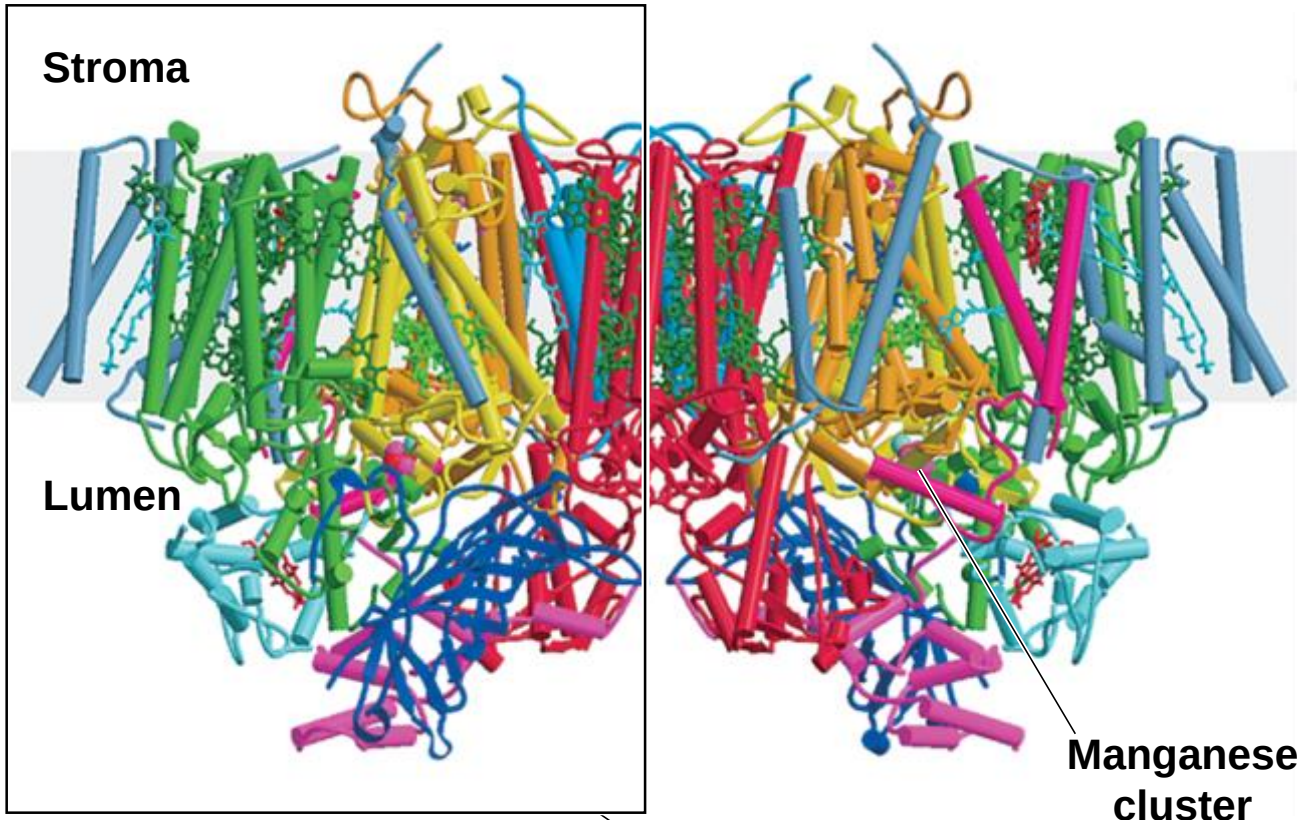
Photosystem II (P680)



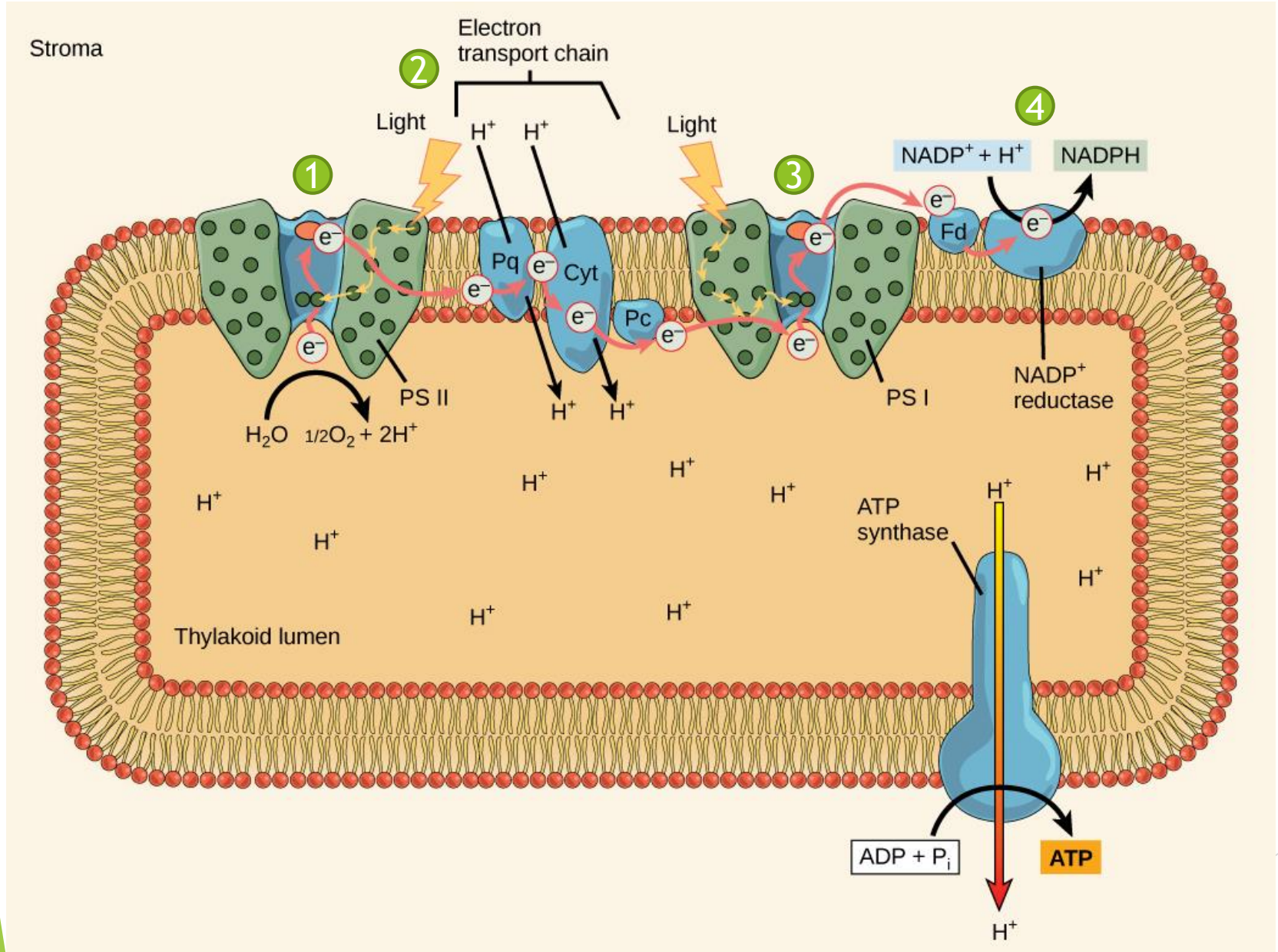
Photosystem I (P700)



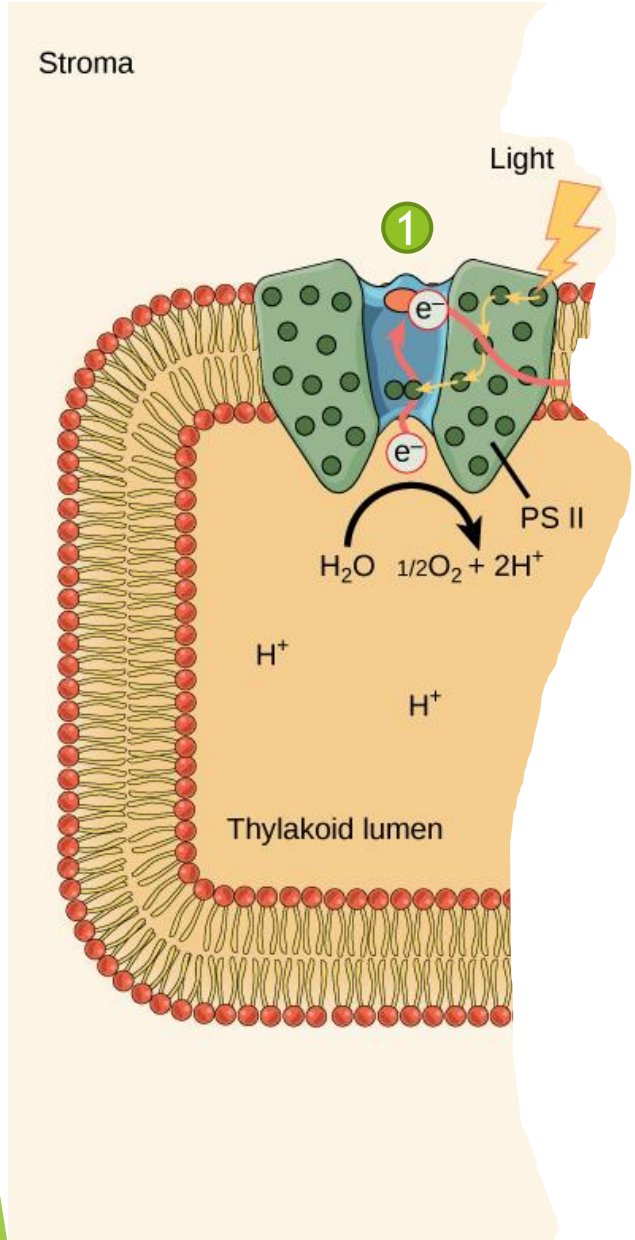
Three-dimensional structure of Photosystem II as determined by X-ray crystallography

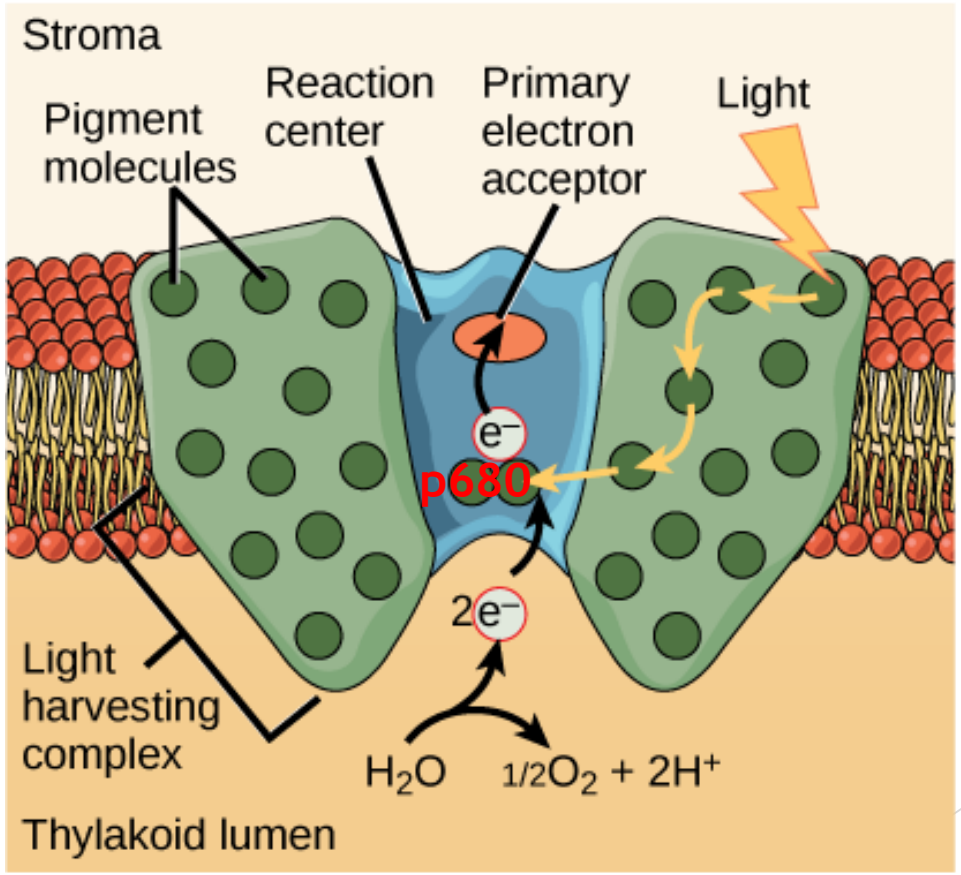


The Light Reactions

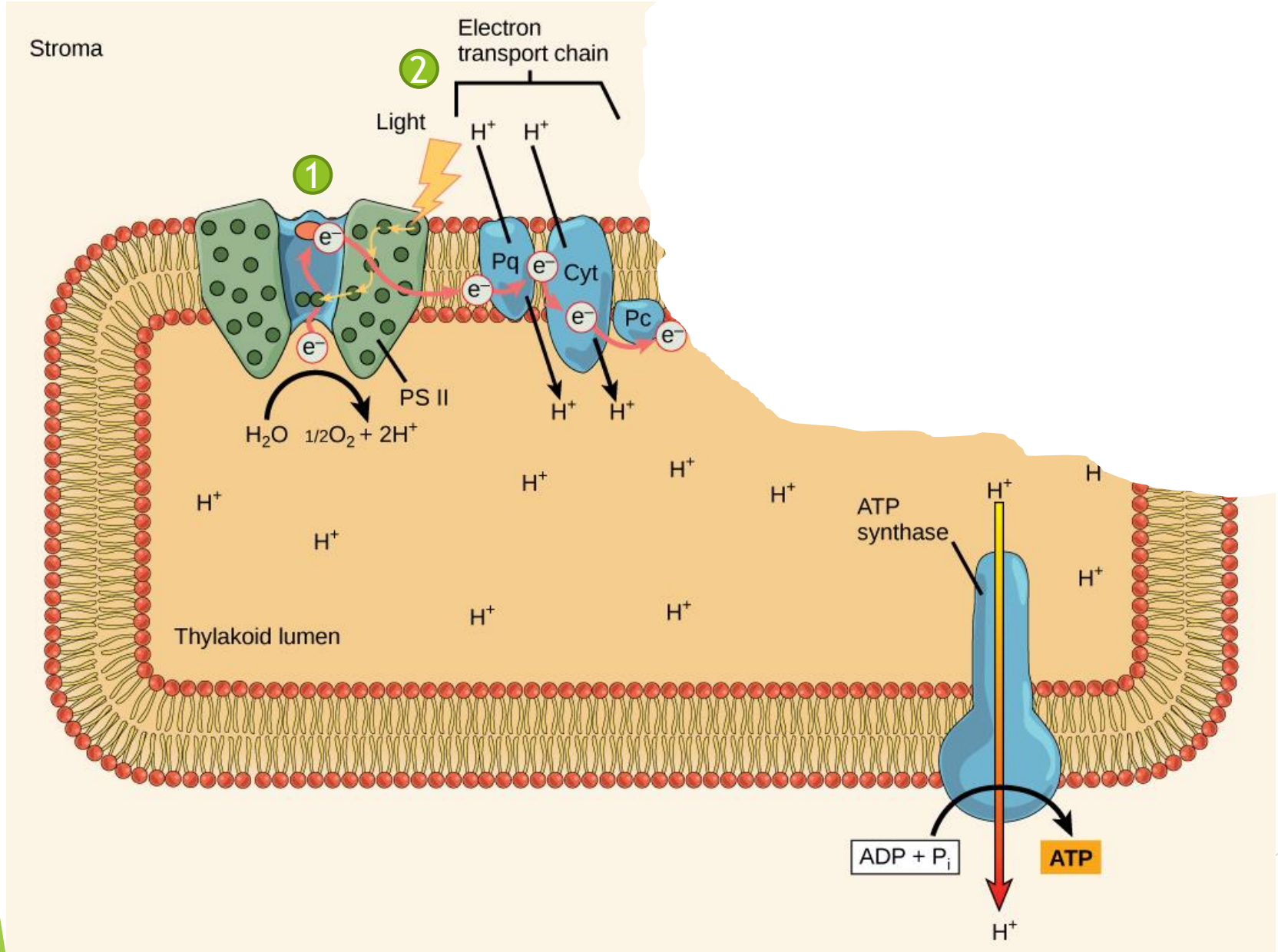


Step 1: Photosystem II

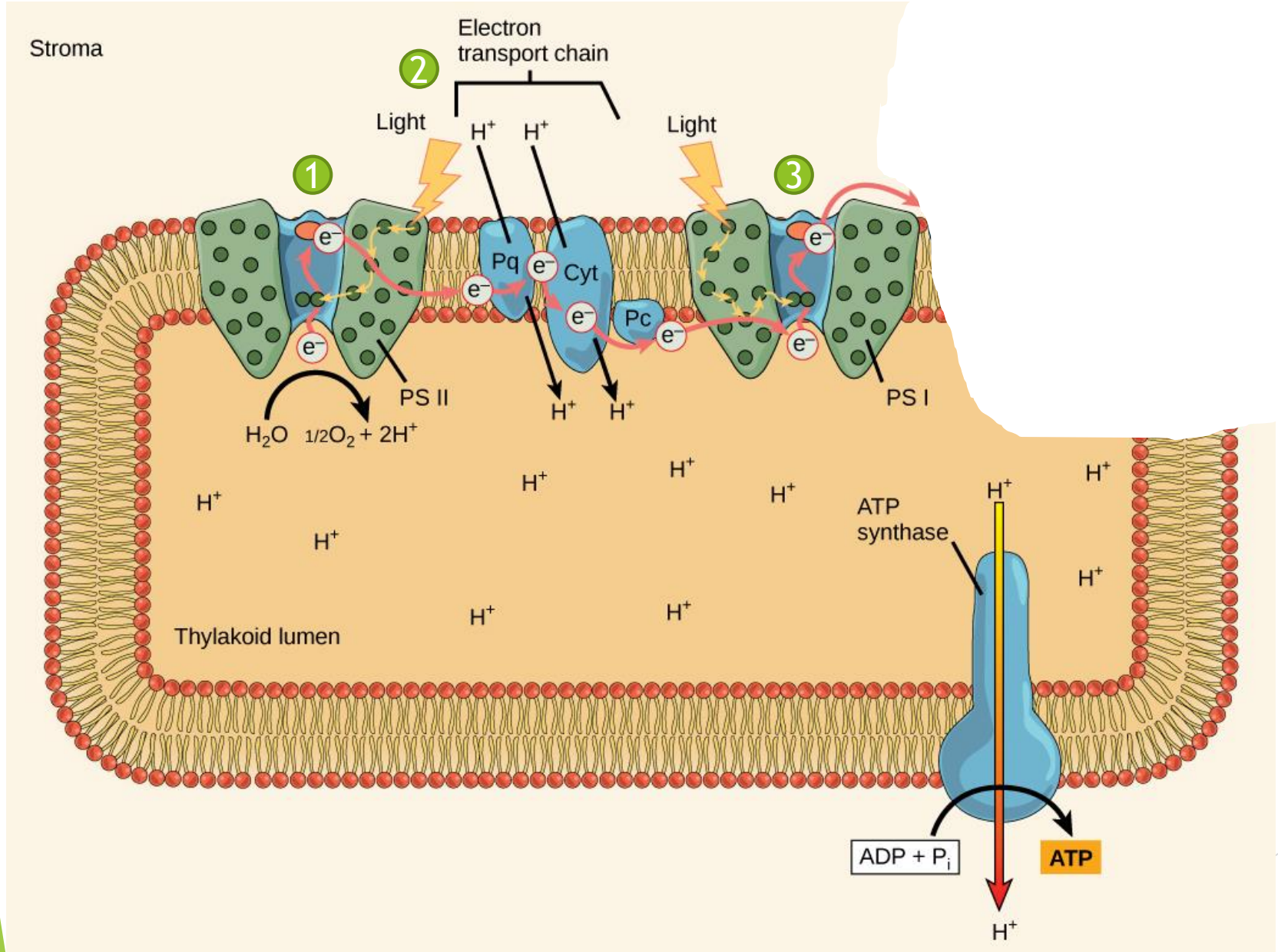




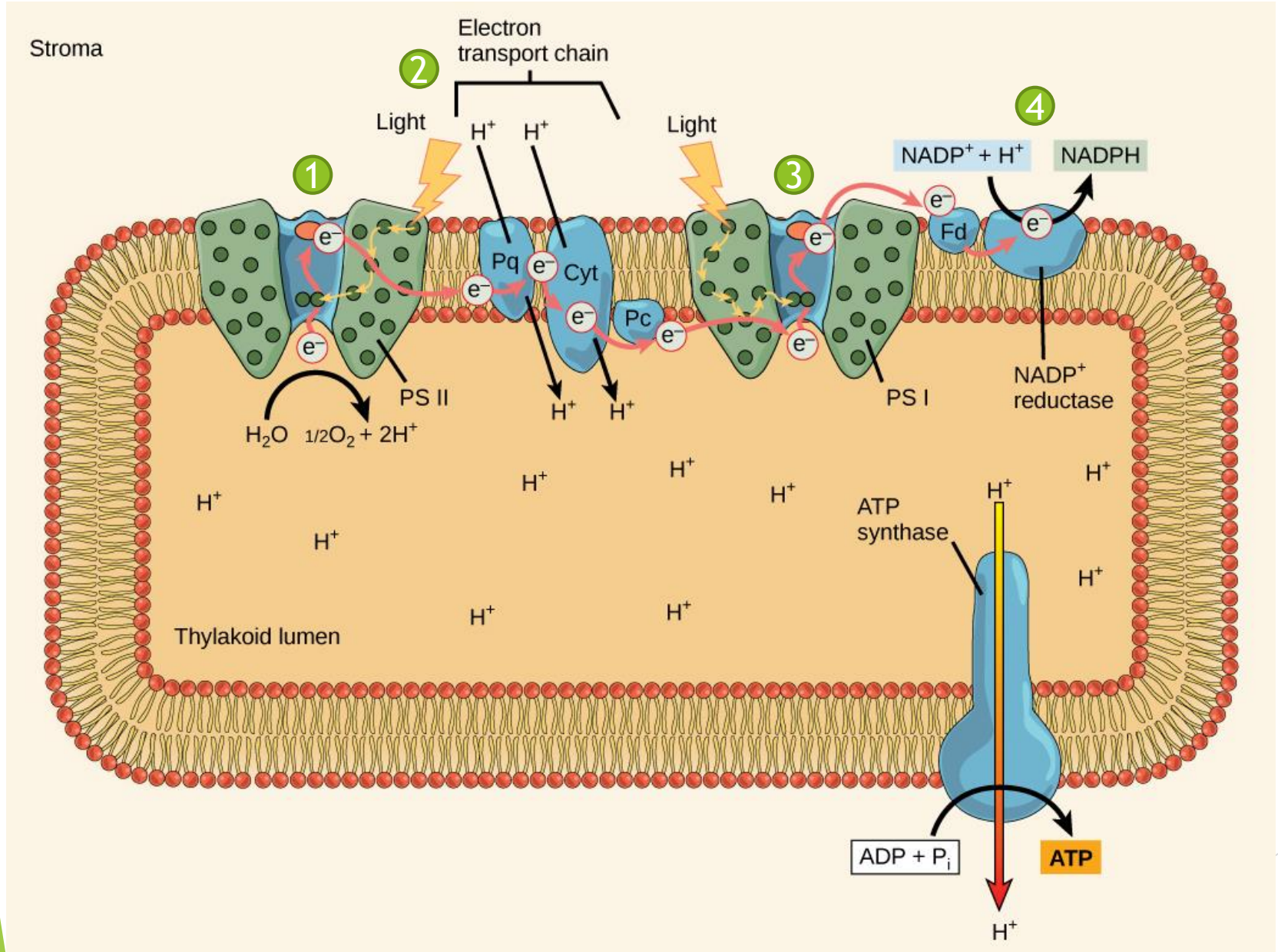
Step 2: PSII-ETC



Step 3: Photosystem I

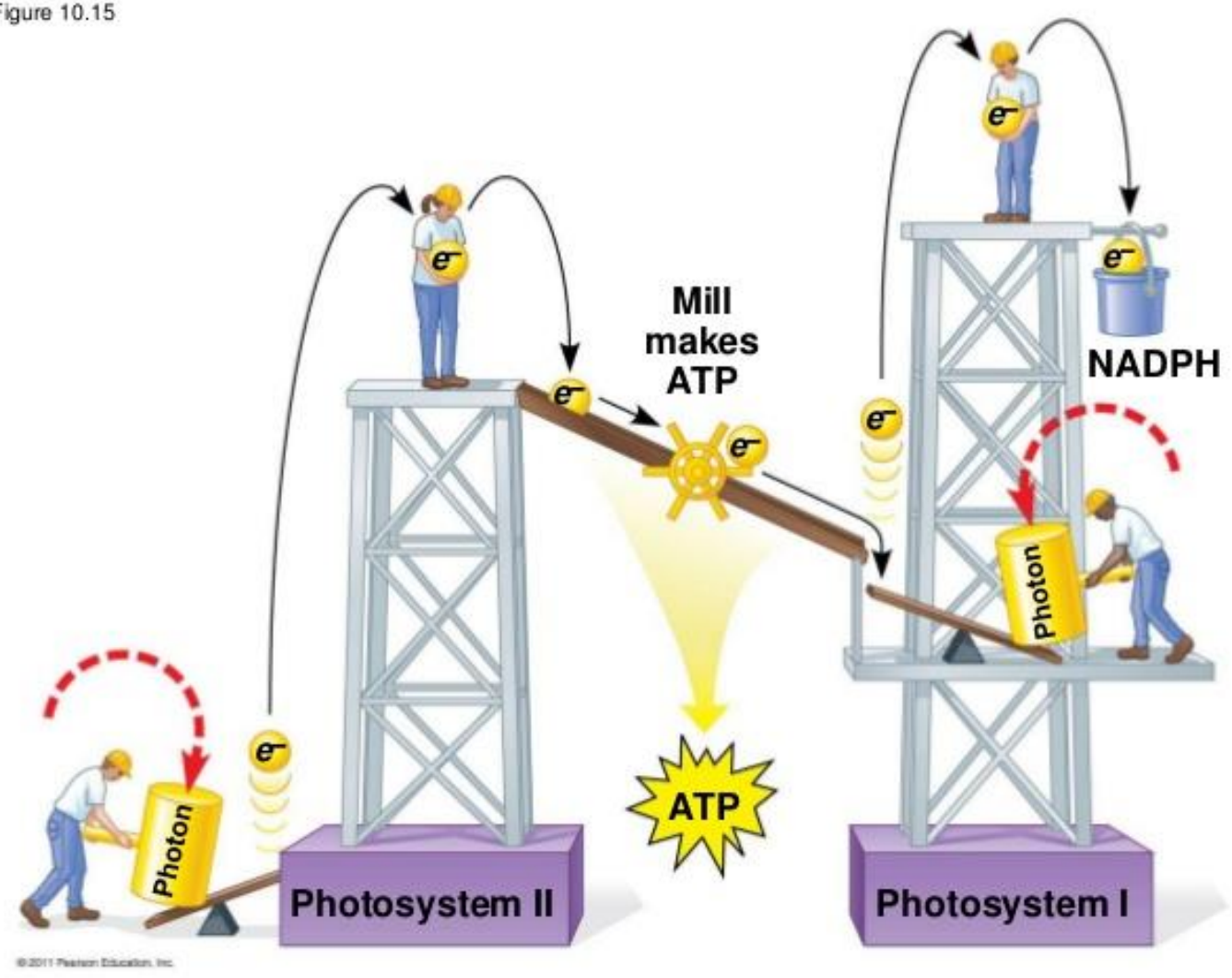


Step 4: PSI-ETC

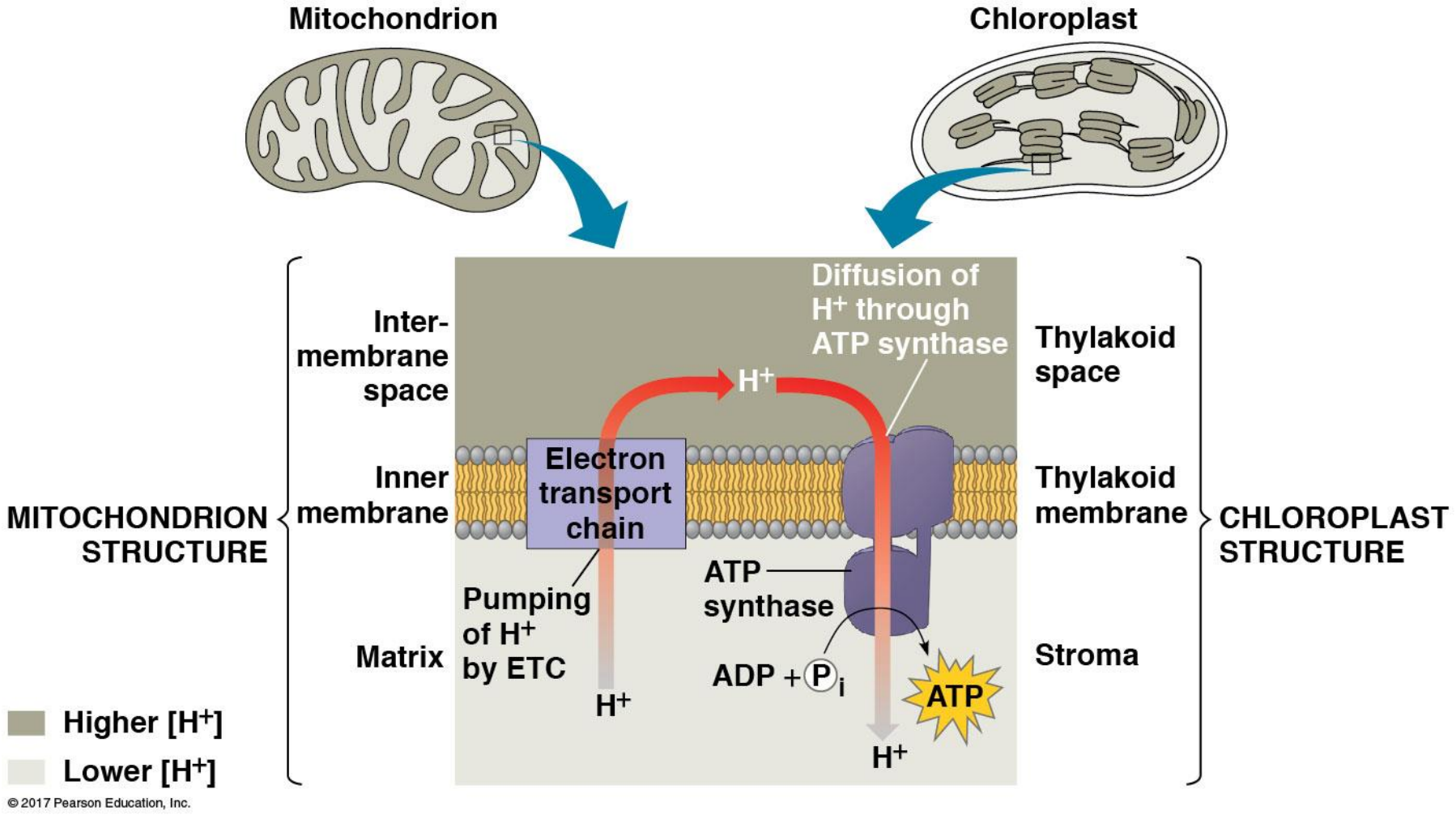


A mechanical analogy for linear electron flow during the light reactions

Figure 10.15



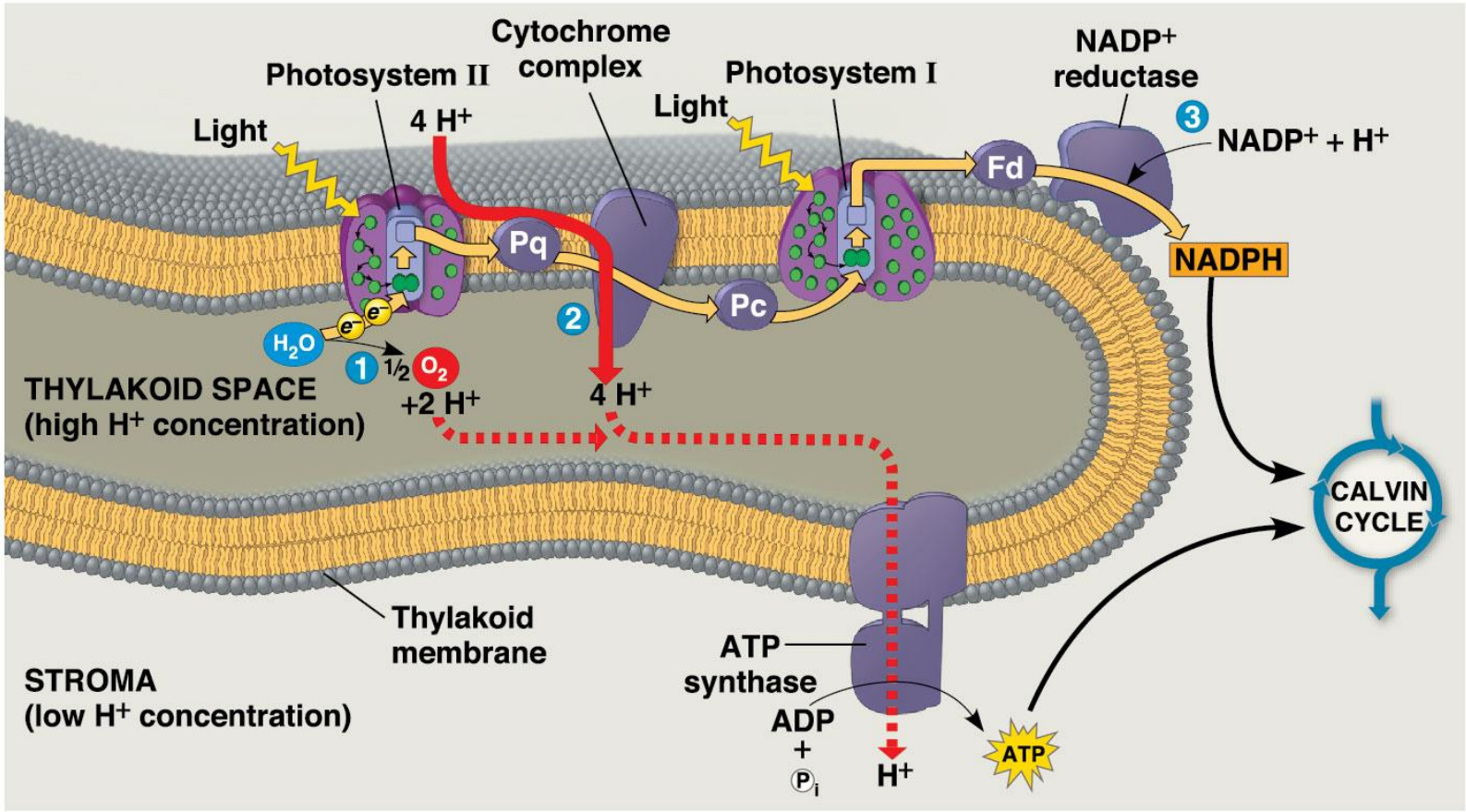
Comparing ATP synthesis by chemiosmosis in cellular respiration *vs*. photosynthesis



Production of ATP by the Chemiosmosis Follow the H+ (red line)

H+ gradient is maintained by

1. **First ETC pumps H+ from the stroma to the thylakoid space**
2. Water is split in the thylakoid space, producing 2H+
3. H+ in the stroma and electrons from the Second ETC reduces NADP+ to NADPH

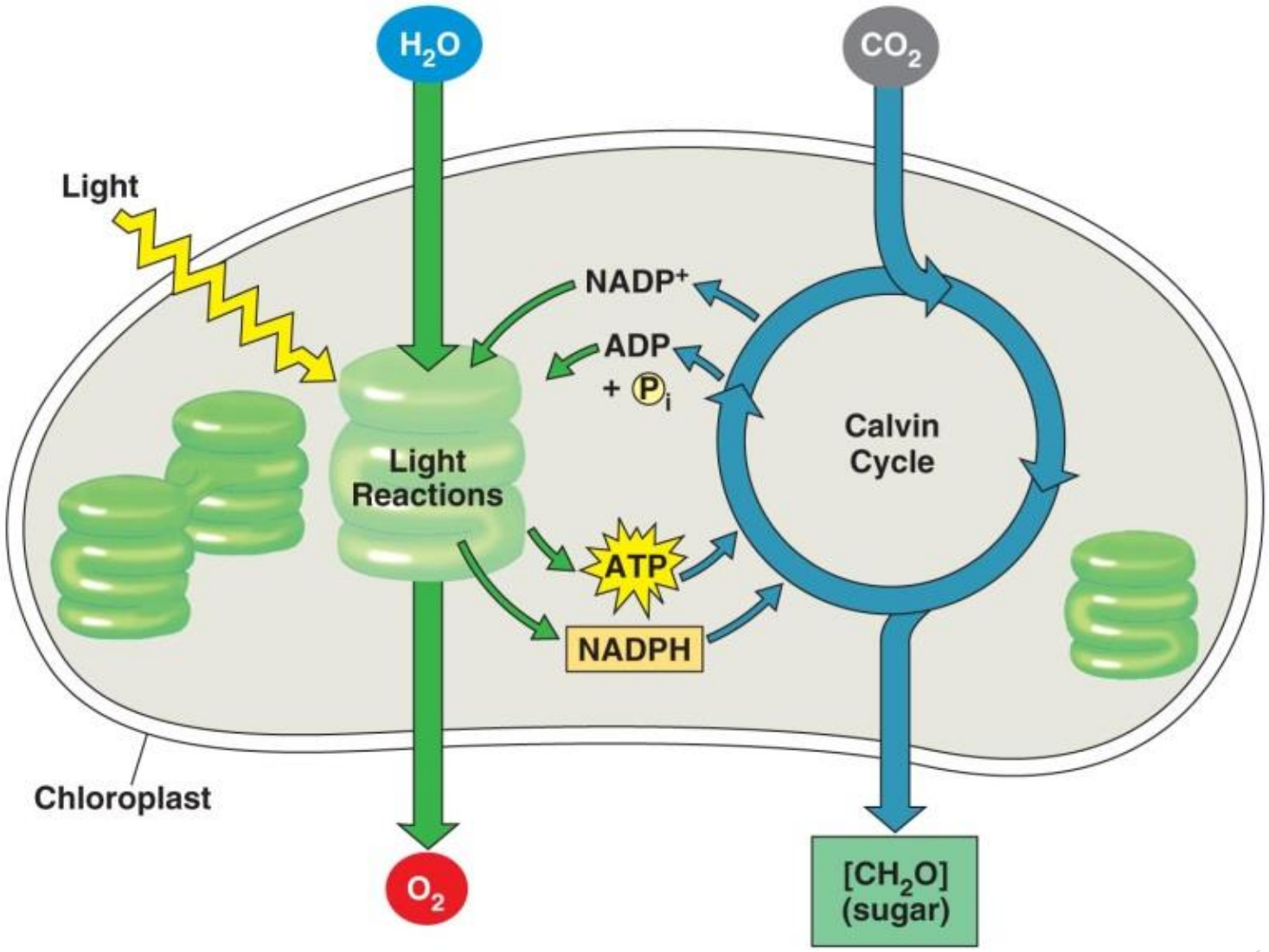


What have we done so far?

- Converted solar energy into chemical energy in the form of **ATP**
- Transferred high energy electrons from water to **NADPH**
- Produced **oxygen gas** as a byproduct

- **This ATP and NADPH, along with carbon dioxide enter the dark reactions or Calvin Cycle**

overall reactions of Photosynthesis



Take Home

1. Pigment molecules absorb light energy, exciting electrons to higher energy states.
2. Photosystems are complexes of proteins and pigments molecules in the thylakoid membrane that absorb solar energy.
3. Photosystem II is able to split water, because p680+ is the strongest biological oxidizing agent we know of. O_2 is released as a byproduct, while the electrons from water then flow down an electron transport chain.
4. The light reaction produce a proton gradient using energy from an ETC. ATP Synthase uses the potential energy in the gradient to make ATP.
5. Photosystem I accepts electron from the ETC and uses light energy to excite them again. The electrons fall down a second ETC to NADP+, which combined with two H+ from the stroma make NADPH.